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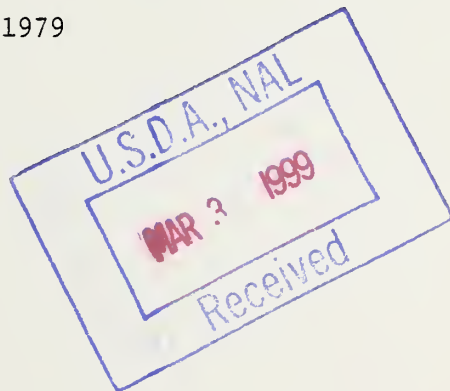
FINAL REPORT

SHELFLIFE, SENSORY, COOKERY AND PHYSICAL CHARACTERISTICS
OF
BACON CURED WITH VARYING LEVELS
OF
SODIUM NITRITE AND POTASSIUM SORBATE

PREPARED FOR
FOOD SAFETY AND QUALITY SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE
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BY THE
MEAT SCIENCE RESEARCH LABORATORY
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INTRODUCTION

This report covers the shelflife, sensory, cookery and physical characteristics of bacon cured with three separate levels of sodium nitrite - potassium sorbate. These three formulations were; (1) 0 ppm nitrite - 0 ppm sorbate, (2) 40 ppm nitrite - 2600 ppm potassium sorbate and (3) 20 ppm nitrite - 0 ppm sorbate. These formulations were used in the manufacture of bacon at four separate processing plants which each had distinctly different processing procedures. Product was evaluated after 10, 30, 50 and 70 days of storage. Details covering the bacon processing protocol, Clostridium botulinum studies and nitrosoamine analyses are covered in reports submitted by Food Safety and Quality Service, USDA and thus are not a part of this report.

Shelflife aspects of the research conducted by the Meat Science Research Laboratory, AR-SEA, USDA includes no microbiological studies. Data presented at this time include means, frequency distributions and bar graphs. Additional statistical analyses are still being performed. However, with the tremendous volume of data even some of the minor differences between formulation or storage time will probably be statistically significant.

The Meat Science Research Laboratory, USDA contracted with North Carolina State University to perform sophisticated flavor and texture profiling of the bacon. This report will present that data plus shelflife, sensory, cookery and physical results of the study.

SUMMARY AND CONCLUSIONS

Allergic, Toxic or Irritant Reactions

1. The skin and throat reactions displayed by eight individuals involved in the study are probably related in some way to exposure to project bacon.
2. Due to the overlap of product testing from the various treatments and plants, there can be no direct relationship made at this time between individual symptoms and any particular ingredient, formulation treatment or processing plant.

Shelflife Studies

1. Bacon manufactured with 0 ppm nitrite had higher frequencies of; (1) pale gray and brown lean color, (2) green fat color, (3) off-odor and (4) surface discoloration than product from other plants.
2. Color values for lean and fat of 40 ppm nitrite - 2600 ppm potassium sorbate bacon were more similar to 120 ppm nitrite bacon than 0 ppm nitrite bacon.
3. Less off-odor was found in bacon formulated with 40 ppm nitrite and 2600 ppm sorbate, especially for Plant IV.

Sensory Studies

Meat Science Research Laboratory

1. Nitrite-sorbate levels, storage times, and processing procedures (processing plant location) had no measurable effect on sensory characteristics.

Flavor and Texture Profile Studies

North Carolina State University

1. A "chemical" like flavor was consistently noted in 40 ppm nitrite - 2600 ppm sorbate bacon manufactured at all plants. However, there was some plant to plant variation as to whether this flavor note was concentrated in the lean or fat component.
2. Panelists occasionally detected a "prickly" feeling in their mouths when testing the nitrite-sorbate bacon.
3. "Microbial" aromas and flavors were found during later stages of storage for 0 ppm nitrite bacon.
4. Differences in formulation had no measurable effect on texture profile parameters for bacon strips, lean and fat portions. The amount of lean in relation to fat exerted more of an influence on textural characteristics.

Cookery Studies

1. Variations in lean to fat rather than nitrite-sorbate levels and storage time were more influential on drip and evaporative losses and strip length and width reductions during cooking.
2. Product from Plant III had the highest drip losses and lowest evaporative losses regardless of formulation and storage time.
3. Bacon from the 40 ppm nitrite - 2600 ppm sorbate formulation when evaluated for aroma during frying had high intensity of "sorbate" aroma. Sorbate aroma was defined as being "sweet," "sweet aromatic," burning sassafras leaves," and "burning plastic."
4. Microbial aromas were found during the frying of 0 ppm nitrite bacon at 50 and 70 days of storage.

Physical Studies

1. The percent lean in relation to fat was as influential as nitrite-sorbate levels and storage times on Instron maximum shear values.
2. Product from Plant III generally had the highest shear force values regardless of formulation and storage time.
3. Bacon strips from both 0 and 120 ppm nitrite bacon were easier to separate from one another than was the case for 40 ppm nitrite and 2600 ppm sorbate bacon.

PROTOCOL FOR SELECTION OF BELLIES IN SENSORY
PROFILE, SHELF LIFE AND COOKING STUDIES

- I. The order of selection by storage time (10, 30, 50, 70 days) was determined at random.
- II. Then the order of selection by sensory vs physical, shelf life and cookery was determined at random.
- III. Then by formulation the belly numbers were picked (with replacement back into the pool) for the various studies.
- IV. Within a storage time by formulation, 2 bellies were designated for combined SEA and NC State sensory and 4 bellies for combined cooking and shelf life studies. Of these 4, 2 were used for cookery, while product from all 4 bellies were used in shelf life studies.
- V. Within bellies product was identified according to belly location (flank, center, blade) for testing. For allocating packages within belly location, it was randomly determined for each belly who would have first random selection (i.e., N.C. State vs SEA).

PROTOCOL FOR SHELF LIFE STUDIES

- I. For the two packages per belly location per belly treatment per plant per storage time; one was randomly assigned to dark storage while the other went to storage under 90 foot candles of incandescent light. This situation applied to the product from two of the four bellies that did not provide packages for cookery studies. In the two bellies that provided product for the cookery and shelf life, product from one belly was stored in the dark, while product from the other was stored in the lighted display case.
- II. Packages stored in the lighted display case were evaluated at 0, 2 and 4 days of display for the attributes identified in Table I. Percent lean in the slice was scored using photographs of slices upon which chemical composition had been determined. On the fourth day the packages were opened and off-odor was ascertained.
- III. Packages stored in the dark were also evaluated at 0, 2 and 4 days of display for the attributes in Table I. Off odor was determined on Day 0 as well as Day 4 since product in this phase was opened initially and stored in the dark to simulate household conditions.
- IV. Product was scored by a four-member evaluation team. Product was coded so that the evaluators had no knowledge of the plants or treatments. Storage temperatures for both light and dark display was 40° F.

PROTOCOL FOR SEA SENSORY STUDIES

- I. A trained 10-member descriptive attribute panel evaluated bacon oven-baked for 13 min for fracturability, hardness, juiciness, total number of chews and mouth coating. For fracturability 8 = extremely fracturably and 1 = extremely rubbery; hardness, 8 = extremely hard and 1 = extremely soft; juiciness, 8 = extremely juicy and 1 = extremely dry; mouth coating, 8 = very slight residue and 1 = very pronounced residue.
- II. At each storage time strips were evaluated from formulation by belly location. In addition, at 30 days of storage cooked dissected lean and fat sections were also evaluated by the panel. Panelists received two pieces (strips or dissected sections) for each sample. The lean sections came from the blade section and the fat section from the flank end.
- III. A panel session consisted of samples from 6 bellies, 2 for each formulation.

PROTOCOL FOR NORTH CAROLINA STATE UNIVERSITY PROFILE PANELS

I. FLAVOR - Cooking procedures for the bacon are identical to that described for SEA cookery studies. A seven-member panel profiles the flavor and texture immediately after cooking.

a. The panel first assess the intensity and type of aromas, followed by placing the sample in the mouth for detecting the individual flavors and intensities. A consolidated profile is derived for each panel sample.

II. TEXTURE - The seven-member panel also assessed texture during the first bite and masticatory phases of chewing. At the first bite stage; hardness, crispness, crumbliness, fibrousness, uniformity and oiliness were determined. During mastication; chewiness, cohesiveness, oiliness, fibrousness, particles of mass and cohesiveness of mass were assessed. The panel members also give a verbal description of the breakdown process in chewing.

III. Packages from the center section of two bellies per treatment per plant are evaluated at each storage time. In addition at the 30-day storage time, dissected lean and fat sections are also profiled.

PROTOCOL FOR COOKERY STUDIES

- I. For each package, two separate rack and pan combinations, each containing 5 strips of bacon, are oven-baked at 425^o F for 13 min. Each strip is measured for length, width (3 locations) and thickness in the precooked and cooked state.
- II. Weights are recorded for precooked, cooked product as well as the drip loss. Evaporative losses are determined by difference.
- III. Ease of separating individual slices from the package is scored using an eight-point scale where 8 = very easy and 1 = very difficult. Verbal descriptions of the cooked product are made for degree of cooked doneness.
- IV. Aroma is assessed by two individuals of bacon from each package cooked in an electric frying pan at 400^o F. The product is cooked 1 min on one side and 1-1/2 min on the other.

PROTOCOL FOR INSTRON TESTS

- II Three slices from each cooked pan (contains five slices) are sheared at three locations. These locations are $1/4$, $1/2$ and $3/4$ the length of the cooked strip. Since the lean to fat ratio can exert a sizeable influence on the shear values, the percent lean is scored by the Instron operator just prior to shearing.
- II. The Instron values are shear force in kg and shear energy in kg-cm.

TABLE 1. BACON SHELF LIFE SCORING SYSTEMS

<u>Muscle Color</u>	<u>Fat Color</u>	<u>Vacuum Score</u>	<u>Purge Score</u>
13 = PSE	8 = White	5 = Excellent	5 = None
12 = Light Pink	7 = Cream	4 = Good	4 = Very Slight
11 = Pink	6 = Peach	3 = Marginal	3 = Slight
10 = Dark Pink	5 = Pink	2 = Poor	2 = Moderate
9 = Orange Pink	4 = Rose	1 = Leaker	1 = Extreme
8 = Rose	3 = Sandy		
7 = Light Red	2 = Brown		
6 = Red	1 = Green		
5 = Slightly Dark Red			
4 = Purple			
3 = Moderately Dark Red			
2 = Brown			
1 = Green			
<u>Off-Odor</u>	<u>Firmness</u>	<u>Surface Discoloration</u>	
4 = No off-odor	8 = Extremely Firm	7 = No Surface Discoloration	
3 = Slight off-odor	7 = Very Firm	6 = Less than 10% S.D.	
2 = Moderate off-odor	6 = Moderately Firm	5 = 10% to 25% S.D.	
1 = Extreme off-odor	5 = Slightly Firm	4 = 25% to 50% S.D.	
	4 = Slightly Soft	3 = 50% to 75% S.D.	
	3 = Moderately Soft	2 = 75% to 90% S.D.	
	2 = Very Soft	1 = 90% S.D.	
	1 = Extremely Soft		

TABLE 2. SCORING SYSTEMS USED BY THE SENSORY PANEL AT THE MEAT SCIENCE RESEARCH LABORATORY, SEA, USDA

Fracturability

- 8 - Extremely fracturable or crispy
- 7 - Very fracturable or crispy
- 6 - Moderately fracturable or crispy
- 5 - Slightly fracturable or crispy
- 4 - Slightly rubbery
- 3 - Moderately rubbery
- 2 - Very rubbery
- 1 - Extremely rubbery

Juiciness

(at 5 chews)

- 8 - Extremely juicy
- 7 - Very juicy
- 6 - Moderately juicy
- 5 - Slightly juicy
- 4 - Slightly dry
- 3 - Moderately dry
- 2 - Very dry
- 1 - Extremely dry

TABLE 2. (continued)

Mouth Coating Effect

- 8 - Very slight residue
- 7 - Slight residue
- 6 -
- 5 - Moderate residue
- 4 -
- 3 - Pronounced residue
- 2 -
- 1 - Very pronounced residue

TABLE 3. CHARACTERISTICS AND NOTES USED BY PROFILE PANELS AT NORTH CAROLINA STATE UNIVERSITY

AROMA

Cured pork	--a general aroma associated with typical cured pork flavor
Fat	--aroma typical of cooked fat
Briny	--aroma of saline solution
Sweet	--aroma associated with basic sweet
Smoke	--aroma typical of meats treated with smoke
Sour	--aroma associated with basic sour
Pig	--off aroma suggestive of live pig
Boar	--off aroma due to sex odor (an organic compound)
Nose burn	--tingling sensation of the nose
Overcooked fat	--self explanatory

FLAVOR BY MOUTH

Salt	--basic flavor perceived by taste buds on tongue
Fat	--flavor typical of cooked fat
Cured pork	--aromatic typical of cured pork flavor
Smoke	--flavor typical of meats treated with smoke
Sweet	--basic flavor as perceived by taste buds on tongue
Sour	--basic flavor as perceived by taste buds
Pig	--off flavor suggestive of live pig
Boar	--off flavor due to sex odor
Old	--off flavor suggestive of deterioration of fresh product
Overcooked fat	--self explanatory
Fat M.F.	--mouthfeel

TEXTURE^a

First bite - Place end of sample between front teeth and bite 1/2" to measure the following:

Hardness --force to bite through sample and bring teeth together
 Crumbliness --degree to which sample breaks into pieces

Mastication - Chew 3/4" piece and evaluate for:

Number of chews --number of chews to prepare sample for swallow
 Cohesiveness (5-7 chews) --degree to which sample is still deforming at 5-7 chews
 Oiliness --degree to which oil or fat is perceived throughout mastication
 Fibrousness --degree to which fibers are perceived throughout mastication
 Coarseness of mass --presence of particles large enough to be distinguished as particles and not mealiness or fibrousness

^aWith the exception of number of chews, textural characteristics scored using 13-point scales which measured the degree of each characteristic; ie., 13 = extreme hardness or force required to bite through sample.

SKIN AND THROAT REACTIONS
OF
SENSORY PANELISTS AND LABORATORY WORKERS--
POSSIBLE ALLERGY TOXIC AND/OR IRRITATION REACTIONS

Laboratory workers at the Meat Science Research Laboratory, ARSEA, USDA, Beltsville, and sensory panelists at North Carolina State University, working on the bacon project, developed various symptoms during the study that might be of an allergy, toxic, or irritation type reaction to compound(s) in the product. Originally, three individuals were thought to exhibit these symptoms at Beltsville; however, the very minor symptoms of short duration by one individual must be questioned. Six individuals at North Carolina State University showed symptoms.

The symptoms observed at Beltsville were facial swelling and numbness, along with reddening of the hands in the first individual. The second individual experienced mainly throat irritation with some facial swelling. The third individual had headaches. In the case of the first two individuals, these symptoms were noted throughout the project's duration and ceased upon completion of the project. The symptoms did not necessarily occur while working with or handling product, but occasionally occurred on weekends several days after working with the product. Symptoms in individuals at Beltsville occurred very early in the project. The reactions in Beltsville personnel were observed after the product from Plant 1 was processed and in the early stages of evaluation, but before product from Plant II had been initially evaluated.

At this time, it was decided following consultation with FSQS that the three individuals at Beltsville should visit an allergist. The allergist reported that the first individual had a slightly positive reaction via a skin scratch test to potassium sorbate. The skin tests showed negative results for potassium sorbate in the second and third individuals. The allergist summarized the situation in the three individuals as such: (1) In the first individual, the reactions were probably due to something other than the materials in the bacon, but caution should be used in working with the product for recurring symptoms; (2) The second individual had a clear-cut relationship of symptoms to the bacon and should discontinue in the type of exposure to the product, which she did; and (3) The third individual had no evidence of reactions to the bacon products being tested. Panelists tasting product at Beltsville reported no symptoms of an allergic, toxic, or irritant reaction to project coordinators.

Approximately five weeks after the evidence of these reactions at Beltsville, the panel leader at North Carolina State University informed Beltsville independently that some panelists at the N. C. State Location were witnessing some reactions. Of the seven panelists, four had expressed witnessing some degree of throat irritation five to six hours after flavor and texture profiling of bacon samples. Another individual occasionally experienced swelling of the lips five to six hours after testing product. A sixth panelist had experienced a foaming in the mouth when certain bacon samples were placed in the mouth. The North Carolina State University panel leader related to the Beltsville project leader that the treatment causing the mouth foaming was 40 ppm sodium nitrite with 2600 ppm potassium sorbate. These panelists had more of

these reactions when 12 samples were evaluated in a given day in contrast to four samples a day. In all individuals, the symptoms were not severe enough to cause absence from work or sensory panel sessions.

Product from the three treatments was provided to the Eastern Regional Research Center in Philadelphia. Chromatographic determinations failed to show any differences between the treatments.

At the conclusion of the study, the symptoms displayed by the panelists and laboratory workers subsided or disappeared. It then became more evident that the symptoms occurring in the individuals were related in some way to participation in the project. Thus, FDA was informed of the situation. FDA is currently developing a protocol for investigating this problem. However, we still don't know, at this date, the actual cause of the symptoms.

The conclusions at this point are:

1. The reactions displayed by panelists and laboratory workers appear to be related in some way to exposure to the project bacon, since, after completion of the study, these symptoms have subsided.
2. If the bacon and its constituents are indeed responsible for the reactions, there may be more than one mechanism involved in triggering the symptoms. Skin contact, placement of product in mouth, or breathing cooking vapors may all be involved.
3. Due to the overlap of product testing from the various treatments and plants, there can be no direct relationship made at this time between individual symptoms and any particular ingredient, formulation treatment, or processing plant.

SHELF LIFE CHARACTERISTICS
OF
BACON

In tables 4-7 inclusive, are located the frequencies of various colors assigned by the shelflife evaluation team to cross-sectional and external portions of sliced bacon. At the beginning of the study, Munsell Color Chips were obtained that would cover the entire range of lean and fat colors expected during storage and shelflife display. Each evaluator used the color chips to identify the appropriate colors in the product. Derivation of frequencies for this report are strictly on a nitrite level basis and do not include storage time or display period values.

For product manufactured at Plant I, the major difference in cross-sectional color between nitrite levels would appear to be in the higher frequency of pale-gray color for 0 ppm nitrite bacon (Table 4). This difference was also noted for the external surface of the packaged bacon. The higher percent of brown color in 0 ppm nitrite bacon compared to the other two formulations occurred mainly in the opened packages. Packages from the 0 ppm nitrite formulation deteriorated in color rather quickly once opened.

Color classification frequencies for product from Plant II reflect a similar trend (Table 5). However the evidence of pale gray, brown and green colors appear higher in the 0 ppm nitrite bacon from Plant II compared to Plant I. Very similar frequencies were noted for external color of 40 vs 120 ppm nitrite bacon from Plant II. The frequencies of cross-sectional and external sliced bacon colors is also similar for Plant III (Table 6) product in contrast to Plant I and II product.

TABLE 4. FREQUENCIES OF COLORS ASSIGNED TO LEAN IN CROSS-SECTIONAL AND EXTERNAL PORTIONS OF SLICED BACON--PLANT I--WHITE^a

Lean Color	Cross Section			Cross Section		
	Level of Nitrite			Level of Nitrite		
	0	40 ^b	120	0	40 ^b	120
Lean Color	<u>Cross-section</u> <u>Level of Nitrite</u>			<u>External</u> <u>Level of Nitrite</u>		
	0	40 ^b	120	0	40 ^b	120
Pale-gray	12.9	9.6	6.3	3.2	0.9	0.7
Light pink	2.4	1.2	1.2	0.5	0.0	0.0
Pink	8.3	4.5	5.9	2.7	0.8	1.1
Dark pink	15.0	14.5	19.4	5.0	4.8	6.4
Orange pink	8.7	10.9	10.1	13.2	15.8	14.8
Rose	10.2	14.4	12.4	14.0	17.8	15.5
Light red	4.6	8.9	9.2	7.7	8.6	11.2
Red	4.2	5.7	7.4	7.4	9.8	12.1
Slightly dark red	4.6	4.9	6.2	9.2	10.6	10.2
Purple	3.3	2.3	2.3	5.2	3.8	5.1
Moderately dark red	1.3	0.9	1.2	2.8	1.8	2.4
Brown	21.4	20.7	16.2	26.4	24.5	17.5
Green	2.9	1.0	2.0	2.6	0.9	2.9

^a Values are in percent of total scores assigned to the particular level of nitrite under either cross-section or external portions.

^b Also has 2,600 ppm potassium sorbate.

TABLE 5. FREQUENCIES OF COLORS ASSIGNED TO LEAN IN CROSS-SECTIONAL AND EXTERNAL PORTIONS OF SLICED BACON--PLANT II--ARMOUR^a

Lean Color	Cross Section			Cross Section		
	Level of Nitrite			Level of Nitrite		
	0	40 ^b	120	0	40 ^b	120
Pale gray	23.4	5.4	5.0	3.6	0.2	0.6
Light pink	5.0	1.4	0.9	0.4	0.1	0.0
Pink	7.0	6.3	4.4	1.4	0.6	1.4
Dark pink	6.5	16.1	17.0	4.9	6.2	6.2
Orange pink	3.1	4.3	6.4	5.0	6.2	8.0
Rose	8.3	20.3	25.8	5.6	8.8	10.8
Light red	3.5	9.0	10.0	5.6	8.8	10.8
Red	2.2	8.1	6.5	5.5	13.0	10.7
Slightly dark red	5.0	9.3	6.1	10.4	16.4	11.7
Purple	3.3	6.3	5.3	6.6	9.0	7.0
Moderately dark red	1.8	1.3	1.3	3.2	2.5	2.5
Brown	23.8	11.8	10.0	33.4	13.3	11.6
Green	6.9	0.4	1.0	7.0	0.4	0.7

^aValues are in percent of total scores assigned to the particular level of nitrite under either cross section or external portions.

^bAlso has 2600 ppm potassium sorbate.

TABLE 6. FREQUENCIES OF COLORS ASSIGNED TO LEAN IN CROSS-SECTIONAL AND EXTERNAL PORTIONS OF SLICED BACON--PLANT III--BRYAN^a

Lean Color	Cross Section			External		
	Level of Nitrite			Level of Nitrite		
	0	40 ^b	120	0	40 ^b	120
Pale gray	18.0	5.3	11.6	8.5	0.2	1.4
Light pink	0.6	0.3	0.5	0.3	0.0	0.1
Pink	3.7	2.6	2.5	2.4	0.7	0.6
Dark pink	11.8	14.3	11.0	8.0	5.8	5.7
Orange pink	4.0	5.5	11.4	4.2	5.3	10.8
Rose	16.2	21.8	15.3	18.3	24.3	16.5
Light red	1.7	4.6	2.7	2.9	4.8	5.6
Red	2.1	7.6	9.0	3.4	10.9	13.2
Slightly dark red	5.0	8.6	8.7	8.6	14.2	14.4
Purple	8.2	9.4	4.9	10.7	11.5	6.8
Moderately dark red	1.3	3.7	2.0	2.6	4.7	3.8
Brown	25.2	15.9	19.2	27.7	16.5	19.7
Green	2.2	0.3	1.0	2.5	0.9	1.4

^aValues in percent of total scores assigned to the particular level of nitrite under either cross section or external portions.

^bAlso has 2600 ppm potassium sorbate.

TABLE 7. FREQUENCIES OF COLORS ASSIGNED TO LEAN IN CROSS-SECTIONAL AND EXTERNAL PORTIONS OF SLICED BACON--PLANT IV--SUGAR CREEK^a

Lean Color	Cross Section			Cross Section		
	Level of Nitrite			Level of Nitrite		
	0	40 ^b	120	0	40 ^b	120
Pale gray	19.9	10.0	6.1	3.0	0.3	0.3
Light pink	0.4	0.2	0.0	0.3	0.0	0.0
Pink	1.4	1.9	1.8	0.1	0.1	0.1
Dark pink	2.8	6.6	10.3	1.5	3.0	3.9
Orange pink	8.7	11.3	13.3	9.6	10.1	10.6
Rose	8.9	16.2	21.1	10.7	17.9	22.3
Light red	1.4	4.1	4.3	2.2	4.8	4.8
Red	4.0	9.5	8.7	6.9	13.6	13.1
Slightly dark red	6.7	6.3	8.4	11.6	11.5	13.7
Purple	4.2	6.4	7.5	6.8	9.5	11.0
Moderately dark red	2.2	2.5	3.0	4.2	4.4	4.8
Brown	35.7	24.2	14.5	41.2	24.3	14.5
Green	3.4	0.7	0.9	2.0	0.6	1.0

^a Values in percent of total scores assigned to the particular level of nitrite under either cross section or external portions.

^b Also has 2,600 ppm potassium sorbate.

The incidence of brown color (associated mostly with opened packages and indicative of discoloration) was higher in cross-sectional and external portions of Plant IV 0 ppm nitrite product than was the case with the previous three plants. The presence of the brown pigmentation was also higher in 40 ppm nitrite - 2600 ppm sorbate product from Plant IV vs the other plants.

Cream, peach and pink colors were the most frequently identified colors in bacon fat regardless of formulation or processing plant location (Tables 8-11 inclusive). Higher frequencies of cream were found in the 40 ppm nitrite bacon fat for Plants I, II and IV. Green pigmentation was higher in the 0 ppm nitrite bacon from all four plants. This would infer that microbiologically induced discoloration occurred due to the lack of nitrite.

Bar graphs depicting the degree of bacon surface discoloration are presented in Figures 1-12 inclusive. Each figure shows the mean discoloration scores for a given formulation from a particular processing plant. These values are shown for the various storage intervals (10, 30, 50, 70 day) in addition to the 2 and 4 days of retail display following the storage intervals.

Packages that were not opened and were subjected to retail display under 90 foot candles of incandescent light underwent less surface discoloration compared to companion packages that were opened and stored in the dark (Figure 1). This trend will be noticeable for all formulations from all plants. At each of the storage intervals, 0 ppm nitrite bacon stored in the dark underwent more discoloration during the 4 day display period than was

TABLE 8. FREQUENCIES OF COLORS ASSIGNED TO FAT OF
SLICED BACON--PLANT I--WHITE^a

Fat Color	Level of Nitrite		
	0	40 ^b	120
White	7.1	13.3	7.9
Cream	18.0	47.9	28.3
Peach	22.8	19.2	22.7
Pink	35.1	10.0	32.0
Rose	5.6	1.5	2.6
Sandy	2.4	4.4	2.4
Brown	0.6	0.4	0.5
Green	8.3	2.9	3.5

^a Values in percent of total scores assigned to the particular level of nitrite.

^b Also has 2600 ppm potassium sorbate

TABLE 9. FREQUENCIES OF COLORS ASSIGNED TO
FAT OF SLICED BACON--PLANT II--ARMOUR^a

Fat Color	Level of Nitrite		
	0	40 ^b	120
White	4.8	18.2	6.2
Cream	18.3	32.3	20.4
Peach	21.6	19.8	22.1
Pink	29.5	20.0	35.9
Rose	5.5	3.3	9.7
Sandy	7.5	1.0	3.7
Brown	0.6	0.0	0.0
Green	12.2	5.4	2.1

^a Values in percent of total scores assigned to the particular level of nitrite.

^b Also has 2600 ppm potassium sorbate.

TABLE 10. FREQUENCIES OF COLORS ASSIGNED TO
FAT OF SLICED BACON--PLANT III--BRYAN^a

Fat Color	Level of Nitrite		
	0	40 ^b	120
White	10.1	11.8	9.3
Cream	31.5	34.2	36.4
Peach	22.2	27.6	23.5
Pink	20.8	18.6	21.5
Rose	2.4	1.2	2.4
Sandy	3.2	1.7	4.4
Brown	0.5	0.8	0.0
Green	9.4	4.2	2.6

^a Values in percent of total scores assigned to the particular level of nitrite.

^b Also has 2600 ppm nitrite.

TABLE 11. FREQUENCIES OF COLORS ASSIGNED TO
FAT OF SLICED BACON--PLANT IV--SUGAR
CREEK^a

Fat Color	Level of Nitrite		
	0	40 ^b	120
White	5.0	11.7	8.4
Cream	30.5	42.8	19.9
Peach	25.4	22.4	23.0
Pink	15.3	11.4	37.5
Rose	1.7	2.4	8.2
Sandy	5.4	2.9	0.5
Brown	0.0	0.1	0.2
Green	16.7	6.3	2.4

^a

Values in percent of total scores assigned to the particular level of nitrite.

^b

Also has 2600 ppm nitrite.

[illegible]

• Packages opened and stored in dark for 4-day display periods
• Packages not opened and stored in light for 4-day display periods.

^a Disc = Surface discoloration, scoring system described in Table 1

the case for companion product stored under the light. Furthermore, packages designated for dark-open storage had greater surface discoloration just after opening than their sealed counterparts. This would suggest that some lean surface discoloration may not be evident through typical bacon packages. This trend is observable on most of the figures. For sealed packages of 0 ppm nitrite bacon from Plant I, the level of discoloration is similar across the storage intervals.

The rate of discoloration of opened 40 ppm nitrite bacon from Plant I is similar to that of 0 ppm nitrite product from Plant I (Figure 2). Bacon formulated from 120 ppm nitrite underwent greater discoloration once packages were opened compared to 0 and 40 ppm nitrite (Figure 3). However sealed bacon from the 120 ppm nitrite formulation exhibited little discoloration over the entire storage period.

Both opened and non-opened packages from the 0 ppm nitrite formulation of Plant II underwent considerable discoloration (Figure 4). This level of discoloration was more extensive than that found for Plant I. The opposite situation was true for 40 ppm nitrite - 2600 potassium sorbate packages that were opened and stored in the dark (Figure 5). The 40 ppm nitrite bacon from Plant II had less surface discoloration during the later phases of the display period compared to the 120 ppm nitrite bacon (Figure 6). The 120 ppm nitrite product had less discoloration from Plant II vs Plant I.

In general, the amount and rate of discoloration in Plant III 0 ppm nitrite packages that were stored in the dark was similar

DISC MEAN

Packages opened and stored in dark for 4-day display periods Packages not opened and stored in light for 4-day display periods.

30

Figure 3. Mean values for surface discoloration of bacon--Plant 1--White 120 ppm nitrite

[illegible]^a Disc = Surface discoloration, scoring system described in Table 1.

DISC MEAN
P

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
Days of Storage	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99

Packages opened and stored in dark for 4-day display periods

^a Disc = Surface discoloration, scoring system described in Table 1.

1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

Days of Storage

31015

1	2
Packages opened and stored in dark for 4-day display periods	Packages not opened and stored in light for 4-day display periods

STORÉLID

to that of Plants I and II (Figure 7). Again, product that remained unopened was scored as having minimal discoloration throughout the total storage period. Opened 40 ppm nitrite bacon from Plant III was given scores for surface discoloration similar to that for 40 ppm nitrite bacon from Plant I (Figure 8). This situation also applied for the 120 ppm nitrite bacon (Figure 9).

Packages of opened 0 ppm nitrite bacon from Plant IV stored in the dark experienced substantial discoloration following all four storage periods (Figure 10). The increase in discoloration noted for non-opened packages of this formulation was not observed in the previous three plants. The differences in mean values are often 2-3 units. Much of the higher frequency of discoloration in this product must be associated with the higher percent of brown color.

The pattern of discoloration for the 40 ppm nitrite product from Plant IV closely paralleled that recorded for Plant I. The 120 ppm nitrite product had similar rates of discoloration as found for this formulation in the other three plants.

Off-odor was scored by the panel at each of the three days of shelflife display for the opened packages and at the termination of the four day period for non-opened packages, when they finally were opened. Slight increases in the presence of off-odor was found for 0 ppm nitrite bacon from Plant I attributable to days of storage and length of display (Figure 13). This situation was also found for 40 ppm and 120 ppm nitrite product (Figure 14, 15). Often the amount of off-odor after several days of display was less than when the package was first opened. Overall, the 40 ppm

34

--- Packages opened and stored in dark for 4-day display periods

^a a Disc = Surface discoloration, scoring system described in Table 1.

Figure 8. Mean values for surface discoloration of bacon--Plant III--Bryan--40 ppm--2600ppm sorbate

	Days of												
	Storage	Storage Plus Display	1	10	11	12	13	14	15	16	17	18	19
Packages opened and stored in dark for 4-day display period	10		1.3	0.6	0.9	1.2	1.5	1.8	2.1	2.3	2.7	3	3.3
	11												
	12												
	13												
	14												
	15												
	16												
	17												
	18												
	19												
Packages not opened and stored in light for 4-day display period	10		1.3	0.6	0.9	1.2	1.5	1.8	2.1	2.3	2.7	3	3.3
	11												
	12												
	13												
	14												
	15												
	16												
	17												
	18												
	19												
DISCOLORATION IN SUPPLIES													
0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.3 2.7 3 3.3 3.6 3.9 4.2 4.5 4.8 5.1 5.4 5.7													

^a Scoring system described in Table 1.

[illegible]

Days of Storage	1	1	1	3	3	3	5	5	5	7	7	7
Days of Storage	3	0	2	4	0	2	4	0	2	4	0	2

Packages opened and stored in dark for 4-day display periods	Packages not opened and stored in light for 4-day display periods

a Disc = Surface discoloration, scoring system described in Table 1

Figure 10. Mean values for surface discoloration of bacon--Plant IV--Sugar Creek
0 ppm nitrite

Days of Storage		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	Days of Storage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
	Days of Storage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
2	Days of Storage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
	Days of Storage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
3	Days of Storage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71																													

^a Disc = Surface discoloration, scoring system described in Table 1.

Figure 11. Mean values for surface discoloration of bacon--Plant IV--Sugar Creek
40 ppm nitrite - 2600 ppm sorbate

DISC MEAN ^a																									
Days of Storage		10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56
		Packages opened and stored in dark for 4-day display periods												Packages not opened and stored in light for 4-day display periods											
5	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

^a Disc = Surface discoloration, scoring system described in Table 1.

ODOR MEAN

5 +

4

3

2

1

Days of Storage 10 12 14 30 32 34 50 52 54 70 72 74 10 12 14 30 32 34 50 52 54 70 72 74

Packages opened and stored in dark for
4-day display periods

Packages not opened and stored in light
for 4-day display periods

Figure 14. Mean values for off-odor in bacon--Plant 1--White--40 ppm nitrite--40 ppm sorbate

ODOR MUAM

Days of Storage	Packages opened and stored in dark for 4-day display periods																Packages not opened and stored in light for 4-day display periods																STUD
	10	12	14	20	22	24	30	32	34	36	40	42	44	46	48	50	52	54	56	60	62	64	66	68	70	72	74	76	78	80			
3.5	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00		
3.0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00		
2.5	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00		
2.0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00		
1.5	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00		
1.0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00		
0.5	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00		

Days of Storage

[illegible]

nitrite formulation had the least amount of off-odor.

A linear response was noted in off-odor for opened packages of 0 ppm nitrite from Plant II up to 52 days of storage and at all four scoring periods for unopened product (Figure 16). The 40 ppm nitrite product had only minimal amounts of off-odor and certainly much less than the 0 ppm nitrite product from Plant I (Figure 17). Scores for the 120 ppm nitrite product were intermediate to those given 0 and 40 ppm nitrite product (Figure 18).

Again off-odor scores of 0 ppm nitrite product (Plant III) were similar to those recorded from Plant I and II product of the same formulation (Figure 19). Thirty day stored samples from 40 ppm nitrite bacon (Plant III) had slightly less off-odor than 10 day product of this (Figure 20) formulation for both opened and non-opened product. The level of off-odor found in this formulation was similar to that recorded for Plants I and II. Only minimal amounts of off-odor were found on 120 ppm nitrite bacon from Plant III (Figure 21).

The occurrence of off-odor in 0 ppm nitrite samples from Plant IV was less than the other three plants (Figure 22). This was unexpected since Plant IV - 0 ppm nitrite bacon had considerable discoloration and brown color. Perhaps not all of the changes in pigment were microbially induced or if microorganisms were involved in the color changes, they may not have produced off-odors. Again very little off-odor was noted in the 40 ppm nitrite bacon (Figure 23). Again, off-odor values for 120 ppm nitrite bacon were intermediate to those of 0 and 40 ppm nitrite product (Figure 24).

[illegible]

Figure 20. Mean values for off-odor bacon--Plant III-- Bryan--40 ppm nitrite - 2600 ppm sorbate

STAGE	STO	Days of Storage	STORAGE PLUS DISPLAY
- J	10	10	*****
	11	11	*****
Packages opened and stored in dark for 4-day display period	12	12	*****
	14	14	*****
	30	30	*****
	32	32	*****
	34	34	*****
	50	50	*****
	52	52	*****
	54	54	*****
	70	70	*****
	72	72	*****
	74	74	*****
2	10	10	*****
	11	11	*****
Packages not opened and stored in light for 4-day display period	12	12	*****
	14	14	*****
	30	30	*****
	32	32	*****
	34	34	*****
	50	50	*****
	52	52	*****
	54	54	*****
	70	70	*****
	72	72	*****
	74	74	*****

0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8

OFF ODOUR

Figure 22. Mean values for off-odor bacon--Plant IV--Sugar Creek--0 ppm nitrite



Packages opened and stored in dark for 4-day display periods

Packages not opened and stored in light for 4-day display periods

Figure 23. Mean values for off-odor bacon--Plant 1V-- Sugar Creek--40 ppm nitrite - 2600 ppm sorbate

[illegible]

In summary, differences between the processing plants in shelflife characteristics of their product were minimal with the exception of the greater occurrence of brown color and lean surface discoloration of 0 ppm nitrite bacon of Plant IV. Less off-odor was associated with bacon manufactured with 40 ppm nitrite and 2600 potassium sorbate.

SENSORY CHARACTERISTICS
OF BACON

MEAT SCIENCE RESEARCH LABORATORY
AR-SEA, USDA

Mean values for sensory characteristics as determined by a trained panel at the Meat Science Research Laboratory, Beltsville, MD, are given in Tables 12-15. No data are given for Plants I and II at 10 days of storage since the panel was not adequately trained to do evaluation at those times of storage. Only the center sections of strips from bacon derived from the center section of the bellies were used in studies involving sensory determinations of bacon strips. However, it is conceivable that variations in lean and fat still had a dramatic effect on sensory evaluations. No apparent trends are noted either respective to nitrite level or storage time for product from Plant I (Table 12). There was a tendency for samples from 0 ppm nitrite bacon to require fewer number of chews. Also, the mouth coating due to fat was slightly less for all treatments following 70 days of storage compared to the other storage times.

No consistent differences in sensory attributes (Table 13) could be attributed to nitrite level in product from Plant II. Samples from all treatments required greater numbers of chews before being able to swallow (no swallowing permitted in the study) following 50 days of storage vs 30 and 70 days of storage. Similar to the product from Plant I, samples at 70 days of storage received lower scores for mouth coating compared to the other storage times. Differences between nitrite levels for sensory characteristics are inconsistent and minimal for Plant III (Table 14). Following

TABLE 12. SENSORY PANEL VALUES FOR BACON STRIPS--PLANT I--WHITE^a

Sensory Characteristic ^b	Bacon Nitrite Level, ppm	Storage Time, Days			
		10	30	50	70
Fracturability	0	--	5.9	6.2	5.2
	40 ^c	--	5.4	5.3	5.3
	120	--	6.0	5.3	5.2
Number of Chews	0	--	19.9	26.2	28.6
	40 ^c	--	24.1	28.5	30.6
	120	--	22.6	29.4	35.5
Juiciness	0	--	5.5	3.9	4.4
	40 ^c	--	5.6	4.5	3.9
	120	--	4.7	4.4	4.3
Mouth Coating	0	--	6.0	6.3	5.3
	40 ^c	--	5.9	5.8	5.2
	120	--	6.2	5.5	5.4

^aPanel conducted at Meat Science Research Laboratory, USDA, Beltsville, MD.

^bScoring systems described in Table 2.

^cAlso has 2600 ppm potassium sorbate.

TABLE 13. SENSORY PANEL VALUES FOR BACON STRIPS--PLANT II--ARMOUR^a

Sensory Characteristic ^b	Bacon Nitrite Level, ppm	Storage Time, Days			
		10	30	50	70
Fracturability	0	--	5.8	4.7	6.7
	40 ^c	--	5.5	5.0	4.8
	120	--	5.6	4.9	5.7
Number of Chews	0	--	25.1	31.0	17.4
	40 ^c	--	26.4	31.2	29.3
	120	--	26.4	33.0	24.9
Juiciness	0	--	3.8	4.0	5.4
	40 ^c	--	4.2	4.8	4.2
	120	--	4.7	4.8	3.1
Mouth Coating	0	--	6.2	5.8	5.6
	40 ^c	--	6.3	5.5	5.6
	120	--	6.2	5.4	5.6

^aPanel conducted at Meat Science Research Laboratory, USDA, Beltsville, MD.

^bScoring systems described in Table 2.

^cAlso has 2600 ppm potassium sorbate.

TABLE 14. SENSORY PANEL VALUES FOR BACON STRIPS--PLANT III--BRYAN^a

Sensory Characteristic ^b	Bacon Nitrite Level, ppm	Storage Time, Days			
		10	30	50	70
Fracturability	0	5.5	5.1	4.9	5.4
	40 ^c	5.8	6.0	5.2	5.2
	120	4.4	4.9	5.5	5.3
Number of Chews	0	27.6	32.4	28.4	27.8
	40 ^c	23.0	26.5	28.6	26.8
	120	31.2	33.8	27.2	30.9
Juiciness	0	4.3	3.7	3.8	4.4
	40 ^c	6.2	4.1	4.6	5.2
	120	4.9	4.4	4.8	5.8
Mouth Coating	0	5.9	5.6	5.4	5.6
	40 ^c	6.2	5.7	5.1	5.2
	120	5.5	4.9	5.2	4.1

^aPanel conducted at Meat Science Research Laboratory, USDA, Beltsville, MD.

^bScoring systems described in Table 2.

^cAlso has 2600 ppm potassium sorbate.

70 days of storage, samples from all treatments were scored higher in juiciness compared to the other storage intervals. Variations in lean to fat are probably responsible for many of the differences in the mean values.

Likewise, sensory values obtained for Plant IV reflect the trend of no apparent influence of nitrite level or storage time on these values (Table 15). Comparisons of the data from each of the four plants indicate very little difference in the magnitude of the values.

In summary, neither nitrite level, storage time, nor processing procedure (Plant location) exerted any consistent effect on the sensory parameters evaluated at the Meat Science Research Laboratory, Beltsville, MD.

TABLE 15. SENSORY PANEL VALUES FOR BACON STRIPS--PLANT IV, SUGAR CREEK^a

Sensory Characteristic	Bacon Nitrite Level, ppm	Storage Time, Days			
		10	30	50	70
Fracturability	0	5.7	5.8	5.6	5.9
	40 ^c	4.9	5.1	4.9	5.5
	120	5.1	5.0	5.5	5.2
Number of Chews	0	24.4	29.5	26.8	23.3
	40 ^c	34.7	31.9	33.2	28.3
	120	30.3	36.8	26.6	29.3
Juiciness	0	3.8	5.4	5.2	6.0
	40 ^c	3.9	4.9	4.1	4.2
	120	4.9	4.5	5.6	5.2
Mouth Coating	0	6.6	5.1	5.0	4.5
	40 ^c	5.9	5.3	5.3	5.4
	120	5.9	4.9	4.8	5.3

^aPanel conducted at Meat Science Research Laboratory, USDA, Beltsville, MD.

^bScoring systems described in Table 2.

^cAlso has 2600 ppm potassium sorbate.

FLAVOR AND TEXTURE
PROFILES OF BACON

NORTH CAROLINA STATE UNIVERSITY

Flavor Profiles

Tables 16-19 inclusive provide verbal summaries of the most prevalent differences in the flavor profiles for bacon obtained by the North Carolina State University panel. Two rather consistent and interesting results were obtained for product from all four plants. First, a "chemical"-like flavor primarily, but also aroma and aftertaste was detected in the 40 ppm nitrite - 2600 ppm sorbate formulation. The presence of this flavor note only in the 40 ppm nitrite samples and not in the other formulations was really the biggest difference reported by the flavor profile panel. On occasion, the panel also recorded a "prickly" mouth feel with the 40 ppm nitrite - 2600 sorbate formulation. This "prickly" mouth feel may in some way be related to the throat irritations reported under the "Allergy, etc." of this report.

The second major flavor difference noted in the study was that of "microbial"-like aromas in 0 ppm nitrite product from three of the four plants. The microbial flavors were described as "moldy," "yeasty" and "sour." For all formulations, salt was the most intense flavor note detected.

In the 0 ppm nitrite product of Plant I (Table 16), microbial-like aromas and flavors occurred in product as soon as 30 days of storage. At the 30 day storage period lean and fat only portions were evaluated in addition to the strips. The "chemical" flavor

TABLE 16. SUMMARIZATION OF FLAVOR PROFILE PANEL RESULTS--PLANT I--WHITE.

Comments For:			
Storage in Days	Aroma	Flavor	Aftertaste
10	Overcooked fat aromas detected in 0 and 120 ppm, but not in 40 ppm nitrite product. Chemical aroma found in 40 ppm nitrite samples.	Profiles similar for all formulations. Salt, fat, cured pork, and smoke most frequently detected flavor.	Profiles similar for all formulations. Salt, fat, cured pork most prevalent aftertastes.
30	Microbial-like aromas detected in 0 ppm but not in 40 and 120 ppm nitrite samples.	Microbial-like flavor found in 0 ppm, but not in 40 and 120 ppm nitrite bacon strips. Lean and fat chemical flavor detected only in 40 ppm nitrite strips and fat portions.	Sour aftertaste found in 40 ppm nitrite product.
50	0 ppm nitrite product had strong microbial off-odors in uncooked form, so not evaluated. Chemical aroma noted in 40 ppm nitrite product.	Chemical flavor and prickly mouth feel found in 40 ppm nitrite product.	Similar profiles found in aftertaste for both 40 and 120 ppm nitrite samples.
70	Same pattern as for 50 days.	Same differences noted as for 50 days. Less intensity of salt flavor in 40 ppm nitrite compared to 120 ppm nitrite.	Same as for 50 days.

appeared to be in the strip and fat sections, but not the lean portion of the 40 ppm nitrite bacon.

Again microbial-like aromas, flavors and aftertastes were present in 0 ppm bacon in Plant II (Table 17). Product from both the 0 and 120 ppm nitrite formulation had sufficient microbial aromas in the uncooked state following 70 days of storage that the panel did not evaluate these products. "Chemical" aromas, flavors and aftertastes were found at all storage intervals for 70 ppm nitrite product. However, in contrast to Plant I 40 ppm nitrite product, 30 day evaluations for Plant II 40 ppm nitrite product showed the "chemical" flavor to be concentrated in the lean rather than the fat.

Overcooked, bitter and sour aftertastes were noted in 40 ppm nitrite product from Plant III (Table 18). "Prickly" mouth feel was also detected in fat samples from the 40 ppm nitrite bacon. Of the cooked and tested samples, "microbial" flavors were not noted for the 0 ppm nitrite formulation. However, packages from this formulation were not tested at 70 days of storage due to "microbial"-like odors in the uncooked state.

Profiles obtained for Plant IV product were similar to those of the other three plants (Table 19). "Chemical" aromas, flavors and aftertastes were prevalent in the 40 ppm nitrite - 2600 ppm sorbate product, while "microbial" aroma was noted in 0 ppm nitrite product evaluated during the later stages of the study. In contrast to Plant III product manufactured with 40 ppm nitrite, Plant IV product of the same formulation had "prickly" mouth feel only in the lean sections.

TABLE 17. SUMMARIZATION OF FLAVOR PROFILE PANEL RESULTS--PLANT II--ARMOUR

Comments For:			
Storage in Days	Aroma	Flavor	Aftertaste
10	Same aromas and intensities as found for Plant I. Chemical aroma found only in 40 ppm nitrite product	Same pattern as for aroma. Also boar-like flavor noted in 40 ppm nitrite samples	Same pattern as for aroma and flavor
30	0 ppm nitrite bacon had microbial-like aroma, while 40 ppm nitrite product had chemical aroma	Same pattern as for aroma. Intensity of salt higher in 120 ppm nitrite product than other formulations. Chemical flavor found in strip and lean, but not fat of 40 ppm nitrite formulation	Same pattern as for aroma
50	0 ppm nitrite product had smoky and microbial-like aromas, while 40 ppm nitrite product yielded chemical aromas	Same pattern as for aroma	No microbial aftertastes found in product from any formulation. Higher intensity of salt aftertaste in 120 ppm nitrite bacon
70	Both 0 and 120 ppm nitrite product exhibited sufficient microbial odor in uncooked state to prevent flavor profiling	Chemical aroma, flavor and aftertaste less for 40 ppm product at 70 days compared to 10, 30 and 50 days of storage	-----

TABLE 18. SUMMARIZATION OF FLAVOR PROFILE PANEL RESULTS--PLANT III--BRYAN

Comments For:			
Storage in Days	Aroma	Flavor	Aftertaste
10	Chemical aroma prevalent in 40 ppm nitrite samples.	Sweet aromatic overcooked fat and chemical flavors present only in 40 ppm nitrite samples.	40 ppm nitrite samples had bitter and chemical aftertastes.
30	Intensity of chemical aroma low for 40 ppm nitrite product.	All formulations had similar profiles, except that a prickly mouth feel was noted in the fat samples from 40 ppm nitrite product.	Chemical aftertaste noted for the lean samples from 40 ppm nitrite.
50	Chemical aroma detected in 40 ppm nitrite bacon.	Chemical flavor and prickly mouth feel found in 40 ppm nitrite product.	Overcooked, bitter, sour and chemical aftertastes at low intensities found only for 40 ppm nitrite product.
70	0 ppm nitrite product not evaluated.	Same pattern of flavors for 40 and 120 ppm product as observed for 50-day product.	Similar aftertaste profiles for 40 and 120 ppm nitrite product.

TABLE 19. SUMMARIZATION OF FLAVOR PROFILE RESULTS--PLANT IV--SUGAR CREEK.

Comments For:			
Storage in Days	Aroma	Flavor	Aftertaste
10	Chemical aroma prevalent in 40 ppm nitrite.	Chemical flavor prevalent in 40 ppm nitrite.	No trends for aftertaste among the formulations.
30	Same results as for aroma at 10 days.	Chemical flavor prevalent in 40 ppm nitrite bacon strips, lean and fat portions; prickly mouth feel found in lean portions of 40 ppm nitrite bacon.	Chemical aftertastes found in strip and lean sections of bacon made with 40 ppm nitrite.
50	Same results as for aroma at 10 and 30 days.	120 ppm nitrite product had overcooked fat flavor; 40 ppm nitrite product had chemical flavors.	120 ppm nitrite product had overcooked fat aftertaste.
70	40 ppm nitrite product had chemical aromas, while 0 ppm nitrite bacon had microbial aromas.	Profile differences for flavor the same as aroma for 70 days.	Profile differences for aftertaste the same as aroma and flavor at 70 days.

In summary, variations in processing procedure employed at the four plants did not appear to influence the flavor profiles of the bacon product. Salt was the most prevalent and intense flavor for all product from all plants. "Chemical" like flavors were consistently detected in bacon manufactured from 40 ppm nitrite and 2600 ppm potassium sorbate. However, there appears to be some processing plant to processing plant variation as to where this flavor and the associated "prickly" mouth feel are located (strip lean or fat portions). "Microbial" aromas and flavors were detected during the later stages of storage for 0 ppm nitrite bacon from three of the four plants.

Texture Profiles

Texture profiles for the center portion of bacon strips from the center section of the bellies are given in Tables 20-24 inclusive. Where no data are given for a particular formulation and storage time, this indicates sufficient microbial aromas in the uncooked form to prevent profiling. Consistent trends respective to formulation and storage time were not observable in the profiles of product from Plant I. Strips from 40 ppm nitrite bacon at 10 days of storage could be characterized as being hard and fibrous with a high degree of oiliness and cohesiveness. Strips from 0 ppm nitrite bacon at 30 days of storage could be characterized as being crumbly, requiring few chews before swallowing while being incohesive, non-fibrous and non-oily. The low number of chews obtained for this product by the North Carolina State Panel (NC State) agrees with that obtained at the

TABLE 20. TEXTURE PROFILE PANEL VALUES FOR BACON STRIPS--PLANT I--WHITE

Sensory Characteristic ^a	Bacon Nitrite Level, ppm	Storage Time, Days			
		10	30	50 ^c	70 ^c
Hardness	0 _b	6.4	6.3	--	--
	40 _b	7.1	7.5	5.9	6.9
	120	6.2	7.0	8.9	6.3
Crumbliness	0 _b	1.7	8.0	--	--
	40 _b	1.2	2.9	1.6	1.0
	120	2.1	2.7	1.3	1.2
Number of Chews	0 _b	17.0	15.4	--	--
	40 _b	23.8	22.5	19.3	24.3
	120	19.2	22.9	26.7	21.7
Cohesiveness	0 _b	5.2	2.8	--	--
	40 _b	8.2	5.3	6.1	7.0
	120	5.0	6.7	8.6	7.5
Oiliness	0 _b	7.3	2.8	--	--
	40 _b	10.3	4.0	5.6	5.1
	120	4.4	5.1	5.4	7.8
Fibrousness	0 _b	5.4	3.1	--	--
	40 _b	9.0	5.9	4.9	6.1
	120	5.4	7.7	9.3	5.8
Coarseness of Mass	0 _b	8.6	8.6	--	--
	40 _b	5.3	8.1	8.5	6.9
	120	6.5	6.8	6.8	8.4

^aDefinitions for characteristics are given in Table 3.

^bAlso has 2600 ppm potassium sorbate.

^c0 ppm nitrite bacon had deteriorated to a state of being undesirable for profiling.

Meat Science Research Laboratory (MSRL). It must be remembered that while differences from the NC State panel appear large, a 13-point scale was employed in profiling for texture.

It is also difficult to detect direct and easily identifiable formulation effects on textural characteristics of bacon from Plant II (Table 21). Storage time also appears to have a negligible effect on textural traits. Variations in lean and fat probably have a much greater influence on textural parameters.

Product from Plant III had low degrees of crumbliness especially during the later stages of storage (Table 22). Fracturability scores given by the MSRL panel (Table 14) do not support this. Other textural parameters did not appear to be greatly influenced by nitrite level. The values also appeared to be similar to those found for Plants I and II. Data presented for Plant IV (Table 23) also reflects inconsistent and minimal differences attributable to either formulation or storage time.

Tables 24-27 inclusive presents texture profile data by processing plant for the lean and fat portions of bacon. These results dramatically illustrate the effects lean and fat have on textural characteristics. Because of these effects a variable such as nitrite level has to produce such an overwhelming influence just to be detectable. Therefore, with this consideration in mind, it was decided before the study to have the NC State panel perform flavor and textural profiles on lean and fat following 30 days of product storage. Demands on panel time and costs prevented profile tests being conducted at all storage periods.

TABLE 21. TEXTURE PROFILE PANEL VALUES FOR BACON STRIPS--PLANT II--ARMOUR

Sensory Characteristic ^a	Bacon Nitrite Level, ppm	Storage Time, Days			
		10	30	50 ^c	70 ^c
Hardness	0 _b	5.8	6.5	7.4	--
	40 _b	5.7	6.7	6.4	7.0
	120	6.7	7.0	8.2	--
Crumbliness	0 _b	3.2	1.0	2.7	--
	40 _b	1.7	1.4	1.3	1.0
	120	2.3	3.9	2.9	--
Number of Chews	0 _b	19.3	28.3	21.4	--
	40 _b	20.0	27.5	23.6	25.0
	120	21.2	19.4	24.8	--
Cohesiveness	0 _b	5.1	6.7	6.1	--
	40 _b	5.9	7.1	6.4	7.1
	120	6.2	5.0	7.0	--
Oiliness	0 _b	5.2	6.3	3.9	--
	40 _b	6.3	5.9	6.4	6.2
	120	5.5	4.4	5.4	--
Fibrousness	0 _b	4.4	6.0	5.5	--
	40 _b	5.0	6.0	6.1	6.0
	120	6.4	3.9	6.4	--
Coarseness of Mass	0 _b	8.3	7.3	7.7	--
	40 _b	6.4	7.1	6.9	8.6
	120	6.4	9.6	7.4	--

^aDefinitions for characteristics are given in Table 3.

^bAlso has 2600 ppm potassium sorbate.

^c0 ppm nitrite bacon had deteriorated to a state of being undesirable for profiling.

TABLE 22 TEXTURE PROFILE PANEL VALUES FOR BACON STRIPS--PLANT III--BRYAN

Sensory Characteristic ^a	Bacon Nitrite Level, ppm	Storage Time, Days			
		10	30	50 ^c	70 ^c
Hardness	0	7.1	7.9	--	--
	40 ^b	6.8	7.8	6.7	6.9
	120	7.7	7.1	5.9	8.7
Crumbliness	0	2.6	1.0	--	--
	40 ^b	1.2	1.0	1.0	1.2
	120	1.8	1.0	1.2	1.0
Number of Chews	0	22.4	27.6	--	--
	40 ^b	19.6	24.8	25.2	23.4
	120	25.5	29.3	26.3	26.2
Cohesiveness	0	5.3	8.2	--	--
	40 ^b	5.4	6.8	6.7	6.8
	120	5.8	8.0	6.2	8.7
Oiliness	0	5.4	8.3	--	--
	40 ^b	5.8	5.9	4.8	6.8
	120	4.9	6.9	7.1	5.8
Fibrousness	0	5.7	7.7	--	--
	40 ^b	6.7	6.4	6.7	6.3
	120	7.0	7.7	5.6	8.8
Coarseness of Mass	0	7.7	5.9	--	--
	40 ^b	6.1	6.6	6.3	9.7
	120	7.4	6.7	8.1	6.6

^aDefinitions for characteristics are given in Table 3.

^bAlso has 2600 ppm potassium sorbate.

^c0 ppm nitrite bacon had deteriorated to a state of being undesirable for profiling.

TABLE 23. TEXTURE PROFILE PANEL VALUES FOR BACON STRIPS--PLANT IV--SUGAR CREEK.

Sensory Characteristic ^a	Bacon Nitrite Level, ppm	Storage Time, Days			
		10	30	50 ^c	70 ^c
Hardness	0	6.8	7.4	--	8.0
	40 ^b	6.1	7.2	8.1	6.9
	120	6.7	9.2	6.7	8.8
Crumbliness	0	1.5	1.0	--	1.0
	40 ^b	1.3	2.6	1.2	1.0
	120	2.4	1.4	1.0	1.2
Number of Chews	0	24.4	26.2	--	25.1
	40 ^b	25.3	23.4	29.2	20.8
	120	20.3	26.5	20.0	28.4
Cohesiveness	0	6.1	8.6	--	7.8
	40 ^b	7.3	6.9	8.2	6.8
	120	6.4	7.1	6.3	9.0
Oiliness	0	5.3	5.8	--	5.7
	40 ^b	6.0	4.4	5.5	6.6
	120	5.3	4.2	5.6	5.1
Fibrousness	0	6.6	8.0	--	8.1
	40 ^b	5.4	5.5	9.3	6.9
	120	6.5	7.7	6.1	9.7
Coarseness of Mass	0	6.3	6.4	--	9.3
	40 ^b	6.1	7.9	6.2	11.0
	120	5.3	6.4	9.8	7.1

^aDefinitions for characteristics are given in Table 3.

^bAlso has 2600 ppm potassium sorbate.

^c0 ppm nitrite bacon had deteriorated to a state of being undesirable for profiling.

Large differences existed between lean and fat portions in the magnitude of certain textural characteristics for Plant I (Table 24). However, differences in textural values within lean or fat attributable to nitrite level are usually small. This would indicate that the inconsistent trends noted in Tables 20-23 are probably the result of lean to fat variations. Sizeable differences occurred between lean and fat for hardness, crumbliness, number of chews, oiliness and coarseness of mass for Plant I product.

Similar patterns are noted in textural differences for Plant II bacon (Table 25). High numbers of chews were required for 40 ppm nitrite fat sections. This was also the case for Plant I samples. In addition, greater fibrousness of the fat was noted for this formulation from both Plants. Fat portions obtained from Plant III (Table 26) had similar crumbliness ratings as lean. Because of this, these samples required greater numbers of chews in preparation for swallowing. Differences attributable to nitrite level in textural characteristics of lean and fat for Plant III bacon appear quite small.

Regardless of nitrite level, textural characteristics were more similar between lean and fat portions for Plant IV product (Table 27) than was the case for the other processing plants. While the fat still had higher levels of oiliness when compared to the lean, as would be expected, scores for hardness, crumbliness, number of chews, cohesiveness, fibrousness and coarseness of mass were similar between lean and fat sections. Again formulation influences on textural characteristics were negligible.

TABLE 24. TEXTURE PROFILE PANEL VALUES FOR LEAN AND FAT PORTIONS.
PLANT I--WHITE^a.

Sensory Characteristic ^b	Bacon Nitrite Level, ppm	Portion	
		Lean	Fat
Hardness	0	8.1	5.0
	40 ^c	8.7	5.5
	120	9.7	3.6
Crumbliness	0	1.4	7.5
	40 ^c	1.0	4.1
	120	1.0	4.4
Number of Chews	0	20.8	13.8
	40 ^c	20.7	17.3
	120	20.6	9.7
Cohesiveness	0	4.9	4.1
	40 ^c	5.4	4.3
	120	7.7	2.9
Oiliness	0	3.0	8.8
	40 ^c	3.2	4.3
	120	2.7	2.9
Fibrousness	0	5.6	1.7
	40 ^c	5.6	5.3
	120	7.4	2.1
Coarseness of Mass	0	9.4	6.1
	40 ^c	10.0	5.7
	120	8.4	2.8

^aLean and fat sections evaluated at 30 days of storage only.

^bDefinitions for characteristics are given in Table 3.

^cAlso has 2600 ppm potassium sorbate.

TABLE 25 TEXTURE PROFILE PANEL VALUES FOR LEAN AND FAT PORTIONS.
PLANT II--ARMOUR^a.

Sensory Characteristic ^b	Bacon Nitrite Level, ppm	Portion	
		Lean	Fat
Hardness	0	8.7	5.4
	40 ^c	9.1	6.4
	120	7.2	4.1
Crumbliness	0	1.4	4.3
	40 ^c	1.0	1.3
	120	1.0	3.2
Number of Chews	0	24.0	13.4
	40 ^c	28.7	23.2
	120	25.7	9.0
Cohesiveness	0	8.2	4.0
	40 ^c	8.1	9.2
	120	8.3	1.9
Oiliness	0	3.0	8.7
	40 ^c	2.9	7.7
	120	3.2	7.4
Fibrousness	0	6.4	4.8
	40 ^c	9.0	8.7
	120	9.2	2.6
Coarseness of Mass	0	5.9	5.1
	40 ^c	6.4	2.7
	120	5.4	4.3

^aLean and fat sections evaluated at 30 days of storage only.

^bDefinitions for characteristics are given in Table 3.

^cAlso has 2600 ppm potassium sorbate.

TABLE 26 TEXTURE PROFILE PANEL VALUES FOR LEAN AND FAT PORTIONS.
PLANT III--BRYAN^a

Sensory Characteristic ^b	Bacon Nitrite Level, ppm	Portion	
		Lean	Fat
Hardness	0	8.6	6.0
	40 ^c	8.1	5.6
	120	7.0	7.3
Crumbliness	0	1.0	1.0
	40 ^c	1.0	1.4
	120	1.0	1.0
Number of Chews	0	24.7	19.2
	40 ^c	24.3	17.3
	120	24.7	21.7
Cohesiveness	0	5.8	8.5
	40 ^c	4.7	5.5
	120	6.0	6.5
Oiliness	0	3.8	12.0
	40 ^c	3.3	10.3
	120	3.7	10.9
Fibrousness	0	5.4	8.6
	40 ^c	6.5	6.8
	120	6.6	8.0
Coarseness of Mass	0	8.4	2.6
	40 ^c	8.6	4.0
	120	8.6	3.3

^aLean and fat sections evaluated at 30 days of storage only.

^bDefinitions for characteristics are given in Table 3.

^cAlso has 2600 ppm potassium sorbate.

TABLE 27. TEXTURE PROFILE PANEL VALUES FOR LEAN AND FAT PORTIONS.
PLANT IV--SUGAR CREEK^a.

Sensory Characteristic ^b	Bacon Nitrite Level, ppm	Portion	
		Lean	Fat
Hardness	0	8.8	8.8
	40 ^c	7.9	6.3
	120	9.0	9.7
Crumbliness	0	1.0	1.9
	40 ^c	1.0	1.0
	120	1.0	1.1
Number of Chews	0	31.4	23.4
	40 ^c	25.3	20.2
	120	25.9	26.6
Cohesiveness	0	8.1	9.1
	40 ^c	6.5	8.2
	120	7.0	10.0
Oiliness	0	3.5	10.3
	40 ^c	2.5	11.2
	120	2.8	8.4
Fibrousness	0	8.7	10.1
	40 ^c	6.0	7.8
	120	5.6	11.3
Coarseness of Mass	0	8.8	4.4
	40 ^c	4.9	5.2
	120	5.1	3.7

^aLean and fat sections evaluated at 30 days of storage only.

^bDefinitions for characteristics are given in Table 3.

^cAlso has 2600 ppm potassium sorbate.

In summary, it would appear that the formulations employed in this study essentially had no effect on textural characteristics of bacon. If a sophisticated technique such as lean and fat profiling shows no differences due to nitrite and sorbate levels, it is doubtful that consumers could detect textural differences attributable to the presence or absence of these ingredients. Unquestionably the proportion of lean in relation to fat can exert a sizeable influence on bacon texture. The data of this study will prove quite valuable if FSQS wishes to develop bacon grading standards.

COOKERY CHARACTERISTICS
OF
BACON

Mean cooking losses in the form of drip and evaporative losses are presented in Tables 28-31. For most storage time-formulation combinations, drip losses were higher than evaporative losses. Where drip losses are higher, this was probably due to higher proportions of fat with less lean in bacon strips used for cooking rather than any particular storage time-formulation combination. Drip losses consistently seem to be highest and evaporative losses lowest in product formulation and storage time (Table 30). Perhaps bellies selected at this plant were unique in chemical composition compared to the other plants. Plant III bellies did appear to be softer and more oily. Bacon processed with 120 ppm nitrite did have high drip loss in combination with low evaporative loss following 50 days of storage regardless of processing plant.

Configurational changes in bacon strip width and length expressed as percent reduction are given in Tables 32-35 inclusive. Generally samples that underwent less reduction in width also had less reduction in length. The greatest changes in width and length for product from Plant I occurred at 30 days of storage (Table 32) regardless of formulations. This situation also occurred in product from Plant II (Table 33). Product from Plant III (Table 34) and Plant IV (Table 35) had greater width and length changes as a result of cooking following 10 days of storage compared to later storage. These results might imply that

TABLE 28. DRIP AND EVAPORATIVE LOSSES AS A RESULT OF COOKING--PLANT I--WHITE^a

Storage Time, Days	Level of Nitrite					
	0		40 ^b		120	
	Drip Loss, %	Evaporative Loss, %	Drip Loss, %	Evaporative Loss, %	Drip Loss, %	Evaporative Loss, %
10	39.6	35.0	37.4	37.2	40.9	29.7
30	40.7	35.6	46.6	27.9	39.8	39.0
50	34.9	37.7	38.7	32.9	47.5	18.0
70	49.8	18.7	48.2	15.2	36.9	31.7

^aPercent values for drip and evaporative losses are reflected as a portion of total cooking losses.

^bAlso has 2600 ppm potassium nitrite.

TABLE 29 DRIP AND EVAPORATIVE LOSSES AS A RESULT OF COOKING--PLANT II--ARMOUR^a

Storage Time, Days	Level of Nitrite					
	0		40 ^b		120	
	Drip Loss, %	Evaporative Loss, %	Drip Loss, %	Evaporative Loss, %	Drip Loss, %	Evaporative Loss, %
10	36.2	45.2	39.5	35.2	32.2	39.4
30	45.2	21.9	36.5	35.6	29.5	42.1
50	48.4	17.1	34.2	33.1	45.2	22.8
70	38.3	35.4	39.6	28.6	38.2	32.0

^aPercent values for drip and evaporative losses are reflected as a portion of total cooking losses.

^bAlso has 2600 ppm potassium nitrite.

TABLE 30. DRIP AND EVAPORATIVE LOSSES AS A RESULT OF COOKING--PLANT III--
BRYAN^a

Storage Time, Days	Level of Nitrite					
	0		40 ^b		120	
	Drip Loss, %	Evaporative Loss, %	Drip Loss, %	Evaporative Loss, %	Drip Loss, %	Evaporative Loss, %
10	49.6	20.2	43.9	29.6	38.4	36.9
30	40.2	22.6	41.5	16.2	46.6	10.9
50	42.7	19.9	34.1	28.8	47.8	10.9
70	45.8	19.9	37.8	30.3	52.1	10.2

^aPercent values for drip and evaporative losses are reflected as a portion of total cooking losses.

^bAlso has 2600 ppm potassium nitrite.

TABLE 31 DRIP AND EVAPORATIVE LOSSES AS A RESULT OF COOKING--PLANT IV--
SUGAR CREEK

Storage Time, Days	Level of Nitrite					
	0		40 ^b		120	
	Drip Loss, %	Evaporative Loss, %	Drip Loss, %	Evaporative Loss, %	Drip Loss, %	Evaporative Loss, %
10	40.9	30.4	43.1	24.9	32.5	43.3
30	33.5	28.5	33.4	28.3	30.1	32.3
50	36.2	25.3	36.5	26.8	36.4	27.2
70	25.5	40.0	36.8	25.7	37.1	21.9

^aPercent values for drip and evaporative losses are reflected as a portion of total cooking losses.

^bAlso has 2600 ppm potassium nitrite.

TABLE 32. BACON STRIP CONFIGURATIONAL CHANGES AS A RESULT OF COOKING---
PLANT I--WHITE

Configurational Change	Bacon Nitrite Level, ppm	Storage Time, Days			
		10	30	50	70
Reduction in strip width at 1/4 strip length, %	0 40 ^a 120	38.0 41.3 30.5	47.7 49.9 47.4	35.1 45.3 30.2	44.4 35.4 36.2
Reduction in strip width at 1/2 strip length, %	0 40 ^a 120	43.8 45.4 34.0	52.1 51.1 48.7	35.1 38.0 21.8	42.3 31.5 39.2
Reduction in strip width at 3/4 strip length, %	0 40 ^a 120	48.2 37.7 36.4	46.8 44.0 45.0	46.1 31.6 21.4	33.3 38.2 38.4
Reduction in strip length, %	0 40 ^a 120	21.1 28.3 24.9	38.2 34.1 38.8	34.0 29.7 29.4	34.0 34.2 32.0

^aAlso has 2600 ppm potassium sorbate.

TABLE 33. BACON STRIP CONFIGURATIONAL CHANGES AS A RESULT OF COOKING--
PLANT II--ARMOUR

Configurational Change	Bacon Nitrite Level, ppm	Storage Time, Days			
		10	30	50	70
Reduction in strip width at 1/4 strip length, %	0	42.3	40.3	38.2	44.2
	40 ^a	40.6	44.2	33.3	33.9
	120	34.3	45.1	28.5	35.4
Reduction in strip width at 1/2 strip length, %	0	41.5	36.7	36.1	44.4
	40 ^a	42.2	43.3	30.8	35.5
	120	36.0	40.2	30.5	33.4
Reduction in strip width at 3/4 strip length, %	0	41.2	39.8	37.4	50.0
	40 ^a	41.7	42.6	33.3	42.1
	120	39.9	43.5	33.6	40.0
Reduction in strip length, %	0	38.4	30.9	39.2	41.8
	40 ^a	32.4	32.3	30.4	28.2
	120	31.8	32.1	36.4	37.6

^aAlso has 2600 ppm potassium sorbate.

TABLE 34. BACON STRIP CONFIGURATIONAL CHANGES AS A RESULT OF COOKING--
PLANT III--BRYAN

Configurational Level	Bacon Nitrite Level, ppm	Storage Time, Days			
		10	30	50	70
Reduction in strip	0	36.6	24.9	41.0	34.5
width at 1/4 strip	40 ^a	37.5	26.4	40.6	34.2
length, %	120	48.3	27.4	33.5	29.2
Reduction in strip	0	34.4	22.9	30.8	31.5
width at 1/2 strip	40 ^a	43.1	28.3	39.4	32.1
length, %	120	44.4	24.7	31.6	30.9
Reduction in strip	0	32.4	31.5	27.7	26.4
width at 3/4 strip	40 ^a	36.0	26.0	37.2	33.9
length, %	120	36.8	21.4	29.7	30.6
Reduction in strip	0	44.6	34.3	37.2	37.4
length, %	40 ^a	39.7	35.9	38.9	39.7
	120	34.9	29.5	33.7	39.6

^aAlso has 2600 ppm potassium sorbate.

TABLE 35. BACON STRIP CONFIGURATIONAL CHANGES AS A RESULT OF COOKING--
PLANT IV--SUGAR CREEK

Configurational Change	Bacon Nitrite Level, ppm	Storage Time, Days			
		10	30	50	70
Reduction in strip width at 1/4 strip length, %	0	35.0	34.8	28.9	35.5
	40 ^a	39.1	33.1	36.1	30.9
	120	40.2	31.9	37.7	34.6
Reduction in strip width at 1/2 strip length, %	0	37.5	31.4	32.3	36.1
	40 ^a	38.2	34.7	33.7	33.8
	120	46.4	35.5	35.8	34.5
Reduction in strip width at 3/4 strip length, %	0	36.6	32.8	29.7	36.1
	40 ^a	38.7	31.3	29.4	30.0
	120	51.0	34.2	40.5	29.3
Reduction in strip length, %	0	36.1	31.8	31.7	35.9
	40 ^a	37.3	29.9	33.9	32.7
	120	37.5	26.5	34.6	24.5

^aAlso has 2600 ppm potassium sorbate.

moisture losses and/or strip shrinkage may occur during prolonged product storage thus producing less strip reduction during cooking. Lean and fat variations totally in the strips and certainly at the locations where measurements were taken probably are responsible for many of the differences in mean values. Level of nitrite and sorbate did not produce any consistent and repeatable trends for configurational changes. Configurational changes did not appear to be closely associated with drip and evaporative losses.

Aromas recorded during frying of bacon by a three member panel are given in Tables 36-39 inclusive. Piggy or non cured aromas during cooking were noted for 0 ppm nitrite product at 10 and 30 days of storage for Plant I (Table 36). These aromas were replaced by "microbial" type aromas in this product at 50 and 70 days of storage. An aroma which was classified as "sorbate" was noted to be most prevalent in 40 ppm nitrite - 2600 ppm sorbate bacon at all storage periods. The reason this name was chosen was due to the similarities in aroma between the bacon during cooking and that obtained when a small amount of potassium sorbate was quickly rubbed in the hands. Other descriptive terms that could be applied to the "sorbate" aroma were sweet, "sweet aromatic," "burning sassafras leaves," "burning plastic." The "sorbate" aroma appeared to be a very low temperature volatile which occurred usually with a high intensity very early in the frying of bacon samples. Salty was the predominant aroma in 120 ppm nitrite bacon up through 50 days of storage, after which microbial aroma was most prevalent at the 70 day storage period.

TABLE 36. MOST FREQUENTLY OBSERVED AROMAS DETECTED DURING COOKING OF BACON--
PLANT I--WHITE

Days of Storage	Level of Nitrite		
	0	40 ^a	120
10	Piggy or non-cured	"Sorbate"	Salty
30	Piggy or non-cured, Smoky	"Sorbate"	Salty, Sweet
50	Microbial	"Sorbate," Cured	Salty, Cured
70	Microbial	"Sorbate"	Microbial

^aAlso has 2600 ppm potassium sorbate.

The most frequently observed aromas during cooking of Plant II bacon (Table 37) were similar to that shown for Plant I product. Microbial aroma appeared as early as 30 days of storage for 0 ppm nitrite product from Plant III (Table 38). Smoky was noted in product from all formulations at some point in the total storage. Where no aroma has been given for a formulation--storage time interval, this means that no particular aroma predominated.

Very marginal evidence of microbial aroma was found for 0 ppm nitrite product from Plant IV (Table 39). This closely related to the low incidence of off-odor noted during shelflife display for this formulation from Plant IV.

In summary, cooking losses appear to be influenced more by other factors (probably lean and fat proportions) than nitrite-sorbate levels and storage times. Bellies from certain geographical areas or processed by certain procedures may influence the ratio of drip to evaporative losses. Configuration changes in width and length of strips do not appear to be influenced by nitrite-sorbate levels but may be greater during earlier periods of storage compared to prolonged storage. A very intense aroma was detected during the frying of 40 ppm nitrite - 2600 ppm sorbate bacon. This aroma was similar in nature to that of potassium sorbate. It is conceivable that consumers could detect this aroma during the cooking of bacon. The 40 ppm nitrite - 2600 ppm sorbate bacon did produce consistently the most occurrences of golden-brown cooked color.

TABLE 37. MOST FREQUENTLY OBSERVED AROMAS DETECTED DURING COOKING OF BACON--
PLANT II--ARMOUR

Days of Storage	Level of Nitrite		
	0	40 ^a	120
10	Overcooked fat	"Sorbate"	Salty, Sweet
30	Cured, Sour	"Sorbate"	Sweet
50	Microbial	"Sorbate"	Salty
70	Microbial	"Sorbate"	Salty

^aAlso has 2600 ppm potassium sorbate.

TABLE 38 MOST FREQUENTLY OBSERVED AROMAS DETECTED DURING COOKING OF BACON--
TABLE III--BRYAN

Days of Storage	Level of Nitrite		
	0	40 ^a	120
10	Piggy or non-cured	"Sorbate"	Salty, Smoky
30	Microbial, Smoky	"Sorbate," Salty	Cured
50	Microbial, Cured	"Sorbate"	Salty
70	-----	Sorbate, Smoky	Smoky

^aAlso has 2600 ppm potassium sorbate.

TABLE 39 MOST FREQUENTLY OBSERVED AROMAS DETECTED DURING COOKING OF BACON--
PLANT IV--SUGAR CREEK

Days of Storage	Level of Nitrite		
	0	40 ^a	120
10	Piggy or non-cured	"Sorbate"	Salty, Piggy or non-cured
30	Salty	"Sorbate"	Cured
50	Salty, Cured	"Sorbate"	-----
70	Cured, Salty	"Sorbate," Smoky	Smoky Microbial

^aAlso has 2600 ppm potassium sorbate.

PHYSICAL CHARACTERISTICS
OF
BACON

Physical or instrumental measurements included Instron single-blade shear force. Since amount of lean in relation to fat had such an effect on results of this study, estimates of the amount of fat were recorded at strip locations where bacon was sheared. Nitrite levels do not appear to have exerted much of an influence on Instron shear force for product from Plant I (Table 40). Storage time also was not a major factor influencing shear force values, except for the lower recordings obtained for 120 ppm nitrite product at 30 days of storage. In certain formulation-storage time categories (0 ppm nitrite - 10 days, 0 ppm nitrite - 30 days, 0 ppm nitrite - 50 days, 120 ppm nitrite - 50 days) increased estimates of percent lean correspondent to higher shear force values. This would be expected since it takes more force to shear through lean than fat. The absence of data in a percent lean category means that no samples were assigned lean percent estimates in that category.

Neither nitrite level nor storage time exerted a distinct influence on shear force values of product from Plant II (Table 41). While increasing estimates of percent lean were frequently associated with increased shear force, this did not occur for every formulation-storage category.

Shear force values were less on an overall basis for bacon strips from 40 ppm nitrite bacon compared to the other two formulations at all storage periods except 30 days of storage (Table 42). Bacon from the 120 ppm nitrite formulation yielded lower shear force values

TABLE 40. INSTRON SINGLE BLADE MAXIMUM SHEAR FORCE VALUES--PLANT I--WHITE

Storage Time, Days	Percent Lean Category, %	Level of Nitrite					
		0		40 ^a		120	
		Mean Estimated Lean, %	Shear Force, Lb.	Mean Estimated Lean, %	Shear Force, Lb.	Mean Estimated Lean, %	Shear Force, Lb.
10	0- 25	25.0	2.8	13.3	3.7	18.3	3.6
10	26- 50	45.2	4.1	42.8	5.4	41.0	4.7
10	51- 75	62.3	4.5	63.8	5.3	57.8	5.0
10	76-100	85.0	5.1	81.7	5.3	--	--
30	0- 25	12.7	3.8	8.1	3.5	16.3	1.4
30	26- 50	40.2	5.0	37.3	4.2	41.8	2.8
30	51- 75	67.3	5.9	64.5	5.0	69.0	3.0
30	76-100	86.0	6.3	85.0	5.0	90.0	1.6
50	0- 25	21.9	4.2	19.1	4.2	20.3	4.5
50	26- 50	37.6	5.1	38.9	5.1	38.9	5.7
50	51- 75	65.0	5.6	67.9	5.0	64.2	6.7
50	76-100	88.8	6.4	80.0	4.7	82.1	7.7
70	0- 25	11.8	4.3	12.5	4.3	19.8	4.1
70	26- 50	41.9	4.8	42.0	4.8	38.2	4.6
70	51- 75	60.8	4.8	64.0	4.4	65.0	4.6
70	76-100	--	--	88.4	4.4	80.0	4.2

^aAlso has 26 ppm potassium sorbate.

TABLE 41. INSTRON SINGLE BLADE MAXIMUM SHEAR FORCE VALUES--PLANT II--ARMOUR

Storage Time, Days	Percent Lean Category, %	Level of Nitrite					
		0		40 ^a		120	
		Mean Estimated Lean, %	Shear Force, Lb.	Mean Estimated Lean, %	Shear Force, Lb.	Mean Estimated Lean, %	Shear Force, Lb.
10	0- 25	13.2	4.3	19.3	4.4	13.4	4.6
10	26- 50	41.4	4.8	40.5	5.9	42.0	5.7
10	51- 75	64.3	4.0	57.6	6.2	59.4	5.9
10	76-100	80.6	3.4	--	--	--	--
30	0- 25	21.2	5.2	17.5	4.1	19.6	3.8
30	26- 50	41.1	5.8	41.9	5.6	43.0	4.5
30	51- 75	64.8	8.2	61.8	5.3	60.9	5.2
30	76-100	78.0	5.3	85.0	7.7	85.0	5.1
50	0- 25	14.8	5.1	20.4	4.7	22.5	6.4
50	26- 50	40.2	5.8	43.8	5.9	43.2	6.2
50	51- 75	60.7	6.2	60.9	6.8	62.7	6.0
50	76-100	--	--	--	--	79.5	5.3
70	0- 25	13.4	3.9	--	--	19.2	4.9
70	26- 50	42.4	5.2	38.8	5.2	42.0	5.3
70	51- 75	59.3	5.8	59.3	5.4	61.0	5.9
70	76-100	84.0	6.2	79.0	6.2	82.5	5.8

^aAlso has 2600 ppm potassium sorbate.

TABLE 42. INSTRON SINGLE BLADE MAXIMUM SHEAR FORCE VALUES--PLANT III--BRYAN

Storage Time, Days	Percent Lean Category, %	Level of Nitrite					
		0		40 ^a		120	
		Mean Estimated Lean, %	Shear Force, Lb.	Mean Estimated Lean, %	Shear Force, Lb.	Mean Estimated Lean, %	Shear Force, Lb.
10	0- 25	20.0	8.1	13.8	3.7	13.1	3.1
10	26- 50	44.1	6.1	40.2	3.6	41.0	4.4
10	51- 75	63.8	6.1	63.0	3.7	63.3	4.7
10	76-100	85.9	6.8	86.3	3.7	88.2	4.4
30	0- 25	15.0	5.5	22.5	5.8	18.0	8.5
30	26- 50	40.8	6.4	41.0	6.0	38.0	6.3
30	51- 75	60.9	6.5	59.1	5.9	65.0	6.5
30	76-100	83.3	5.4	93.3	8.6	80.0	7.3
50	0- 25	13.5	6.4	13.6	4.6	10.8	7.1
50	26- 50	39.7	6.1	40.7	4.6	42.6	6.7
50	51- 75	60.4	5.8	56.3	5.2	59.8	6.8
50	76-100	--	--	--	--	82.0	6.8
70	0- 25	--	--	15.0	4.1	23.3	5.5
70	26- 50	44.5	6.4	42.2	5.7	41.0	5.8
70	51- 75	63.5	6.6	64.6	5.7	64.7	6.6
70	76-100	80.0	6.6	80.0	4.4	80.0	6.1

^aAlso has 2600 ppm potassium sorbate.

regardless of estimated lean at 10 days of storage compared to the other storage times. Increasing estimates of lean were associated with less of an increase for shear force in Plant III product than was recorded for Plants I and II. Generally, shear force values were higher for Plant III compared to Plant I and II.

Plant IV bacon strip shear force values were not greatly affected by nitrite level or storage time (Table 43). In about 50% of the storage time-formulation categories, increasing estimates of lean were associated with increased shear force values.

Bacon strips from 0 ppm and 120 ppm nitrite packages were easier to separate from each other than was the case for bacon strips from the 40 ppm nitrite - 2600 sorbate formulation. This might imply that some adhesive characteristics may exist between bacon components and nitrite-sorbate ingredients.

In conclusion, percent lean versus fat was found to influence shear force values as much as nitrite-sorbate levels or storage time. Again, product from Plant III seemed to respond differently (higher shear force values) than was the case for the other three plants.

TABLE 43 INSTRON SINGLE BLADE MAXIMUM SHEAR FORCE VALUES--PLANT IV--SUGAR CREEK

Storage Time, Days	Percent Lean Category, %	Level of Nitrite					
		0		40 ^a		120	
		Mean Estimated Lean, %	Shear Force, Lb.	Mean Estimated Lean, %	Shear Force, Lb.	Mean Estimated Lean, %	Shear Force, Lb.
10	0- 25	20.0	5.0	13.7	4.8	8.1	5.2
10	26- 50	40.6	6.1	46.1	7.2	40.3	5.2
10	51- 75	64.9	6.9	64.2	6.7	63.4	5.3
10	75-100	80.0	7.3	83.1	8.2	82.6	5.9
30	0- 25	16.7	6.2	12.8	6.3	17.7	6.4
30	26- 50	39.2	6.7	40.1	6.5	42.3	6.8
30	51- 75	64.3	6.5	62.9	6.7	65.2	6.4
30	76-100	89.0	6.9	--	--	90.0	5.8
50	0- 25	19.5	6.2	15.6	5.3	13.5	5.8
50	25- 50	41.2	6.8	41.2	6.2	41.7	6.8
50	51- 75	64.3	7.2	60.8	7.4	61.1	7.0
50	75-100	--	--	80.0	7.2	82.9	7.8
70	0- 25	16.1	6.8	11.0	5.5	15.1	4.9
70	26- 50	39.2	6.5	41.6	6.8	38.4	6.4
70	51- 75	66.7	6.5	61.2	6.9	63.5	7.5
70	76-100	81.7	7.1	85.8	7.3	79.8	8.0

^aAlso has 2600 ppm potassium sorbate.

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